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Influence of Crop-Pasture Rotation and Tillage System on Yields of Wheat, Soybean, Barley, Sorghum and Sunflower in Uruguay

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Abstract: Crop rotation and tillage practices are important keys to enhance crop yields in template regions. No-tillage has been developed to produce greater crop yields compared to conventional ones, but limited research has been conducted regarding crop rotation and tillage systems involving several cash crops in continuous agriculture or crops-pasture rotations. The objective of this study was to determine the grain yield response of no tillage cropping sequence integrated by wheat/soybeans, barley/sorghum, fallow/sunflower to three agriculture intensity in no-tillage, (i) continuous cropping system (NT_{CC}); (ii) cropping sequence followed by a short pasture composed by a mixture of red clover (*Trifolium pratense L.*) and chicory (*Cichorium intybus*) (NT_{C-SP}); (iii) cropping sequence followed by a long perennial pasture of birdsfoot trefoil (*Lotus corniculatus*), white clover (*Trifolium repens L.*) and tall fescue (*Festuca arundinacea L.*) (NT_{C-LP}). A crop-pasture rotation with conventional tillage widely used in Uruguay was included as a check management (CT_{C-LP}). The experiment was located in western Uruguay and established in 1994 on a clay loam soil (Typic Argiudoll).Yields obtained from 2001 to 2007 were analyzed. Principal Components Analysis (PCA) was used to describe the total grain yield variability among treatments in each crop along with annual weather condition and soil depth. There Multivariate analysis of grain yield indicated that NT had not negative effects on grain yields of complex double cropping sequences. There was an important effect of weather condition during the growing season of evaluated crops however interaction with tillage or rotation systems was not evident. Only soybean grain yield was significantly reduced in CT_{C-LP}. Soil depth was important to achieve high soybean and sunflower yields in NT systems under water stress conditions. NT_{CC} resulted in similar grain production than both crop-pasture rotations NT_{C-SP} and NT_{C-LP}. NT treatments showed similar results than the check management CT_{C-LP}, indicating that tillage may be eliminated without negative effects on crop yield.
Key words: No tillage; crop-pasture rotation

INTRODUCTION

In agricultural systems, soil quality is thought in terms of productive land that can maintain or increase farm profitability, as well as conserving soil resources so that future farming generations can make a living (Hulugalle and Scott, 2008).

In Uruguay, soil fertility depletion and soil erosion are major limiting factors in crop production. Management practices that can modify soil quality include tillage systems and crop rotations. Since No-tillage (NT) has been found to improve soil quality and diminish soil erosion, NT crop-pasture rotation has become a more sustainable soil use under Uruguayan ecological and productive conditions (García-Préchac et al., 2004). This, however, has not always been found to be beneficial for grain yield. Adoption of NT system had been frequently associated to small impact on yields in well drained soils, adequate nitrogen fertilization or dry seasons (Martens, 2000; Díaz-Zorita et al., 2002; Zentner et al., 2002; Triplett and Dick, 2008). However many studies conclude that grain yield under conventional tillage (CT) is greater than NT in wet years (López-Bellido et al, 1996; Lopez-Bellido et al, 2000).

Uruguay climate is characterized by an average of 1200 mm of annual precipitations with a high seasonal variability. Potential evapotranspiration is greater during summer than winter season, consequently, water deficit commonly occurs in summer (maximum in January, 100-mm) whereas water excess frequently occurs in winter (maximum in July, 60 mm). Double annual cropping system is possible due to water availability and regimen of temperature over the year. Under this climatic conditions NT may be an advantage for summer crops and could diminish winter crop yields. Sustainable agriculture has revitalized the interest in crop rotations. The positive effects of crop-pasture rotations are well-documented (Pierce and Rice, 1988; Mcewen et al., 1989; Christen et al., 1992; García-Préchac et al., 2004). Yields are higher when cereals follow a legume pasture or legume cover crop as they save nitrogen. Crop diversification and crop sequencings can influence plant disease risk in cropping systems (Rasmussen et al., 1997; Krupinsky et al., 2004)

Cropping and tillage systems could be an important key for enhancing crop yields in template regions, but limited research has been done to test this hypothesis. The objective of this study was to determine the impact of crop-pasture time ratio on grain yield of annual crops in a NT system. Crop-pasture rotation with conventional tillage, widely used in Uruguay, was included as a checking management.

MATERIALS and METHODS

The experiment was located in western Uruguay and established in 1994 on a clay loam soil (Typic Argiudol). Yields obtained from 2001 to 2007 were analyzed and presented here. The study site was under continuous cropping in conventional tillage among 1940 to 1970. Since 1970 until 1993, the experimental area was under crop-pasture rotation (periods of 3-years each) with conventional tillage.

Double annual crop sequence integrated by wheat/soybeans (*Triticum aestivum* L./ *Glycine max* (L.) Merr.); barley/sorghum (*Hordeum vulgare* L./ *Sorghum bicolor* L. Moech.), fallow/sunflower (*Helianthus annuus* L.) was tested in three rotation systems under no-tillage (NT): (i) continuous cropping system (NT_{C-C}); (ii) cropping sequence followed by a short pasture composed by a mixture of red clover (*Trifolium pratense L.*) and chicory (*Cichorium intybus*) (NT_{C-SP}); (iii) cropping sequence followed by a long perennial pasture of birdsfoot trefoil (*Lotus corniculatus* L.), white clover (*Trifolium repens L.*) and tall fescue (*Festuca arundinacea L.*) (NT_{C-LP}). A crop-pasture rotation with conventional tillage widely used in Uruguay was included as a check management (CT_{C-LP}).

The experiment had eighteen plots of 500 m^2 (10m by 50 m) distributed on a landscape with a slope from 1% to 4.5%. Soil depth varies from 0.43 m to 0.85 m (top and bottom of the slope, respectively). Each crop and pasture combination were present every year but there were not simultaneous replications.

Wheat and barley were sown early June each year. Soybean and sorghum were sown early December immediately after wheat and barley harvest, respectively. Sunflower was sown after sorghum during early October.

Glyphosate, at a rate of 1.5 to 2.0 kg a.i. ha^{-1}, was applied in all treatments including NT, depending on weed infestation and weather conditions. Seedling was done with no-till drill seeder with double disc opener using row distance of 0.17 m. in winter crops and 0.5 m in summer crops.

The tillage treatment included a combination of chisel plow to a depth of 20-25 cm followed by disking to a depth of 10-15 cm previous to winter crops and sunflower. A disk harrow to a depth of 15-20 cm followed by a field cultivator to a depth of 10-15 cm was used previous soybean and sorghum.

Perennial pastures were planted in association (in the same planting operation) with the last wheat crop of the annual crops sequence.

Pre and post emergent herbicides were applied in all treatments to control weeds as needed. Nitrogen and phosphorus fertilization was added according to the soil test and plant level analysis.

Grain yield was determined by harvesting the central 160m2 of each plot with a combine harvester. Yields are expressed as kg ha^{-1} with 13% of grain humidity.

Total Soil depth and thickness of the Ap horizon (Ap) and clay horizon (Bt) were determined using a hydraulic soil core sampler. Three cores were taken per plot.

Daily weather conditions were recorded with a Campell Pacific Station located 100 m from the experiment. Each wheat and barley growth season was characterized by: rainfall during of month of July (RainJul), August (RainAug), October (RainOct)and November(RainNov); average of minimal temperature of June, July and August (TempJun, TempJul and TempAug respectively); means and maximum temperature during the month of October (TmaxOct and TavgOct) and November (TmaxNov and TavgNov); sunshine hours during September, October and November (SunSep, SunOct and SunNov respectively); an estimation of photothermal coefficient (PhotCoef) defined as sunshine hours and average temperature ratio.

$$PhotCoef = ((SunOct / TavgOct) + (SunNov / TavgNov))$$

Season growth of summer crops were characterized by: rainfall and potential evaporation of a class A tank (ETa) of the months of January (RainJan), Februray (RainFeb) and March (RainMarch) and a water stress index of January, February and March (WSIJan, WSIFeb, WSIMar respectively) defined as relation of ETa and rainfall ratio .

Statistical analysis was conduced to describe the association treatments with weather condition and soil characteristics. The treatments were defined as a tillage system–pasture rotation–year combination, as described above. Principal Components Analysis (PCA) was used to describe the total variability present in each crop with the different treatments, for multiple variables grouped into environment variables (Temperatures, Rain, different stress indexes and photothermal coefficient), soils variables (A horizont, Bt and Depth) and yield variables. The variables included in the analysis were standardized. All meaningful loadings (i.e. >0.30) were used to run another PCA performed to describe and to interpret the grain yield variability of groups of treatments. The ANOVA and Tukey (P<0.05) tests were used to identified similar years, which were used as random replicates of treatments. Statistical analyses were done with the SAS GLM and PRINCOMP procedures (SAS Institute, 2009).

RESULTS

Yield as function of year and treatments.

The lowest grain yields of wheat and barley were obtained in 2002, but the performance was more affected in barley (Table 1).

Table 1. Mean grain yields (Mg ha^{-1}) of wheat, barley, soybean, sorghum and sunflower in the long-term experiment in Paysandú, Uruguay (2001-2008).

	Grain yield (Mg ha^{-1})				
Year	Wheat	Soybean	Barley	Sorghum	Sunflower
2001	3.22abc	-	3.83a	-	-
2002	2.05c	-	0.75c	4.67a	1.77b
2003	4.24a	2.03a	3.95a	5.08a	3.55a
2004	3.36ab	1.33b	3.28a	4.24a	1.15b
2005	3.13abc	1.58b	3.83a	4.91a	1.52b
2006	2.74bc	1.74b	2.12b	4.31a	1.47b
2007	3.63ab	1.92b	2.14b	5.37a	1.68b
2008	3.77ab	2.32a	3.75a	5.87a	2.82a

Means followed by the same letter within a column are not significantly different at P ≤0.05 (Tukey test).

The highest yields were obtained in four years for wheat (2003, 2004, 2007 and 2008) and five years for barley (2001, 2003, 2004, 2005 and 2008).There was a different behavior among yields of wheat and barley in 2001, 2005 and 2007. Soybean and sunflower had a similar pattern. They obtained higher yields in 2003 and 2008. Sorghum yield was stable among years.

Years were classified in high yield environment (HYE) or low yield environment (LYE) for each crop. All yields followed by an *a* or *a* and *b* were taken as HYE whereas those followed by a *c* were considered as LYE (Figure 1).

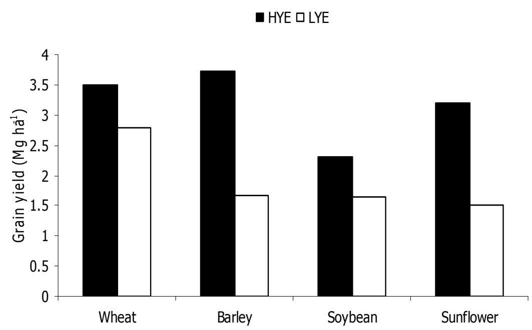

Figure 1. Grain yield of wheat, soybean, barley and sunflower (Mg ha^{-1}) in the long-term experiment in Paysandú, Uruguay (2001-2008). Bars represent average for high yield (HYE) or low yield (LYE) environments.

Except for sorghum, every crop significantly reduced its yield in LYE and that reduction was more evident in barley and sunflower than wheat and soybean (55% versus 19% and 29% respectively).

To check treatment effect (tillage system and crop-pasture rotation) yield environment classes were used as replication (Table 2).

Grain yields of wheat and sorghum were not affected by the evaluated treatments. The lowest grain yields were obtained with $CT_{C\text{-}LP}$ management for soybean and $NT_{C\text{-}SP}$ in barley and sunflower. No differences in yield were found between NT_{CC} and $NT_{C\text{-}LP}$ for any crop.

Table 2. Effect of tillage system and crop-pasture rotation on yield (Mg ha^{-1}) of wheat, soybean, barley, sorghum and sunflower in the long-term experiment in Paysandú, Uruguay (2001-2008).

	Treatment [1]			
Crop	$CT_{C\text{-}LP}$	$NT_{C\text{-}LP}$	$NT_{C\text{-}SP}$	NT_{CC}
Wheat	3.04 a	3.17 a	3.22 a	3.22 a
Soybean	1.51 b	1.89 ab	1.81 ab	2.10 a
Barley	3.72 a	2.74 ab	2.56 b	2.86 a
Sorghum	4.26 a	4.89 a	5.10 a	5.04 a
Sunflower	2.88 a	2.59 ab	2.20 b	2.29 ab

[1] NT_{CC}= continuous cropping system; $NT_{C\text{-}SP}$ =cropping sequence following by a short pasture; $NT_{C\text{-}LP}$=cropping sequence following by a long perennial pasture; $CT_{C\text{-}LP}$= cropping sequence following by a long perennial pasture with conventional tillage.

Means followed by the same letter within a row are not significant different according Tukey test at P ≤0.05.

Principal component analysis of tillage system and crop-pasture rotation as a function of environment variables and grain yield.

The PCA output for grain yield, weather conditions, soil depth and depth of Ap and Bt horizon is summarized in Table 3.

Two principal components (PC) explained 41%, 85%, 53%, 63% and 64% of the total variance for wheat, barley, soybean, sorghum and sunflower respectively. Considering only eingen vectors ≥ 0.3, only temperature and rainfall during winter crop season integrated PC1 and PC2. Grain yield was relevant in barley but not in wheat (0.3 and 0.08 respectively). Soil depth and PhotCoef. during grain filling were the higher PC2 coefficient in barley.

Grain yield, rainfall and temperature during early growth stages were positively weighted on Barley PC1 while RainOct. and TmaxOct. were negatively valued. Thus, higher grain yield in barley was associated with environments with low temperature and rainfall during early growth stages and was negatively affected by high temperature and excessive rainfall during October. Surprisingly no a clear association between wheat grain yield and weather conditions was observed.

On the other hand, yields of soybean and sunflower were negatively associated with water stress index for the period January to March. The depth of the Bt horizon was positively associated with yield of sunflower, but negatively associated with soybean yield. Sorghum grain yield was not affected by weather conditions or soil depth.

A second run of PCA was performed based on grain yield and uncorrelated variables with relevant loading.

This analysis was used to screen the effect of weather condition (year) and tillage-cropping system combinations (Figure 2). Since sorghum yield was not affected by year or treatment, it was not included in this second run.

Barley grain yield was also determined by year weather conditions however it was explained primarily by PC2 (Table 2). Lower yields of 2002 (rainfall of November and low PhotCoef.), 2006 and 2007 (excessive rainfall during October) was not improved by crop rotation or tillage system. Higher yield of 2008 was suited in superior left quadrant (low rainfall during October and November) including all NT combinations.

Wheat yield was determined by year weather conditions. Lower grain yields are suited in lower right quadrant (2002) and were associated with high rainfall during the month of July and November (PC1) and low SunSepOctNov. (PC2). None treatment showed high yield in this weather condition. High yield are suited in the left quadrant associated with rainfalls in October. All observations correspond to the year 2007. Other year-treatment combinations are suited around the middle point following an average performance.

Table 3. Principal components analysis (PCA) considering temperature, rainfall, sunshine hours, soil depth, pasture production and grain yield for each crop. Only principal components with eingen value>1 and that explain >0.2% were retained.

	Winter crops			
	Wheat		Barley	
Variables	PC1	PC2	PC1	PC2
Eingen value	3.84	3.09	3.89	2.92
Proportion	0.23	0.18	0.23	0.17
Soil parametrs				
A	0.21	-0.17	0.28	0.03
Bt	-0.28	-0.08	-0.16	0.34
Total soil depth	-0.18	-0.13	-0.06	0.29
Pasture	0.06	-0.05	0.02	0.07
Early growth stages				
TminJun.	-0.04	-0.24	0.03	-0.37
TminJul.	-0.31	-0.15	0.40	0.13
TminAug.	-0.17	-0.44	0.37	-0.26
RainJun.	-0.05	0.20	-0.06	0.02
RainJul.	-0.31	-0.35	0.38	-0.20
RainAug.	-0.35	0.08	0.26	0.30
Heading and grain filling				
TmaxOct.	-0.13	0.54	-0.17	0.46
TmaxNov.	-0.20	-0.11	0.30	0.16
RainOct.	0.43	0.08	-0.36	-0.12
RainNov.	-0.16	0	-0.01	-0.10
HelSON	-0.33	0.38	-0.07	0.25
PhotCoef.	-0.36	0.17	0.17	0.09
Yield	-0.08	0.12	0.32	0.34

	Summer crops					
	Soybean		Sorghum		Sunflower	
Variables	PC1	PC2	PC1	PC2	PC1	PC2
Eingen value	3.25	1.39	3.20	1.86	3.06	2.03
Proportion	0.40	0.17	0.40	0.23	0.38	0.25
Soil parametrs						
Ap	-0.10	-0.05	0.30	-0.08	-0.25	-0.24
Bt	0.28	0.64	-0.12	0.63	0.09	0.54
Soil depth	0.27	0.64	-0.11	0.63	0.13	0.39
Water stress index						
WSIJan.	0.38	-0.7	0.41	-0.04	0.46	0.16
WSIFeb.	0.48	-0.22	0.42	0.37	0.42	-0.39
WSIMar.	0.38	-0.28	0.45	-0.16	0.47	0.01
WSIAvg.	0.53	-0.23	0.54	0.14	0.54	-0.19
Yield	-0.21	-0.01	-0.20	-0.12	0.06	0.53

Table 4. Principal component analysis (PCA) standardized score based on grain yield and uncorrelated variables with relevant loading.

	Principal component	
	PC1	PC2
Wheat		
Proportion	0.4	0.25
RainJun.	-0.08	0.6
RainOct.	-0.54	-0.17
RainJul.	0.52	-0.05
SunSepOctNov.	0.14	0.75
Yield	-0.34	0.22
Barley		
Proportion	0.29	0.24
A	0.21	0.47
Bt	-0.1	0.12
RainNov.	0.62	-0.16
RainOct.	-0.51	-0.43
PhotCoef.	-0.02	0.32
TminJun.	-0.1	0.63
Yield	-0.1	0.63
Soybean		
Proportion	0.34	0.21
A	-0.11	0.13
Bt	0.56	-0.34
Soil depth	0.52	-0.34
Pasture	0.22	-0.37
WISFeb.	0.42	0.58
Yield	-0.42	-0.52
Sunflower		
Proportion	0.33	0.26
A	-0.38	-0.02
Bt	0.35	-0.44
Soil depth	0.32	-0.29
WISJan.	0.53	0.2
WISMar.	0.45	0.32
Yield	0.34	-0.4

Only a trend to better yields was registered with $NT_{C\text{-}SP}$ in high yield years (2008 and 2003). Results obtained for barley in the PCA with the criteria described for Table 3 are inconsistent with those obtained in the second PCA based on grain yield and uncorrelated variables with relevant loading.

According to ANOVA $NT_{C\text{-}SP}$ produced the lowest average grain yield but PCA is indicating a possible year*treatment interaction. Although $NT_{C\text{-}SP}$ produced the best average yield in HYE this treatment determined the lowest yield in LYE (3782 kg ha^{-1} versus 1384 kg ha^{-1} respectively).

Soybean yield was negatively associated with WSIFeb (Figure 2c). Thus, the lowest yield was obtained in 2004 (superior right quadrant), with high water stress during the month of February. For this weather condition all treatments showed a similar performance. Though in the superior left quadrant are suited lower yield associated with medium WSIFeb, this plots represent sites with shallow soil.

Sunflower yields were more negatively associated with WSIJan than with WSIFeb (Figure 2d). With high WSIJan high sunflower yields were obtained even if soil was depth but not when shallow.

DISCUSSION

PCA approach allowed the discrimination of weather, soil and management effects on grain yield of different crops as reported by Sena et al. (2002). Biplots permitted the quantification of the relative effect of each studied component and the investigation of the interaction between weather condition and crop rotation-tillage system interaction as well.

Results from this study are in agreement with the revised literature for wheat and barley. Wheat is negatively affected by excessive rainfall during heading and grain filling (Gonnet and De León, 1984b; Verón et al., 2004; Alvarez, 2009) whereas barley has a higher yields during dry years (Setter and Waters, 2003).

Interestingly, no differences were observed between $LC_{C\text{-}LP}$ and NT treatments. Literature indicates that conventional tillage is a favorable soil management to winter crops in wet conditions and poorly drained soils (Cannel and Finey, 1973; Cannel et al., 1980; Lopez-Bellido, 1996). We used Bt thickness as an indicator of soil drainage and even though 2001 to 2008 were classified as wet years our results do not show relationship between winter crop grain yield and Bt for those years.

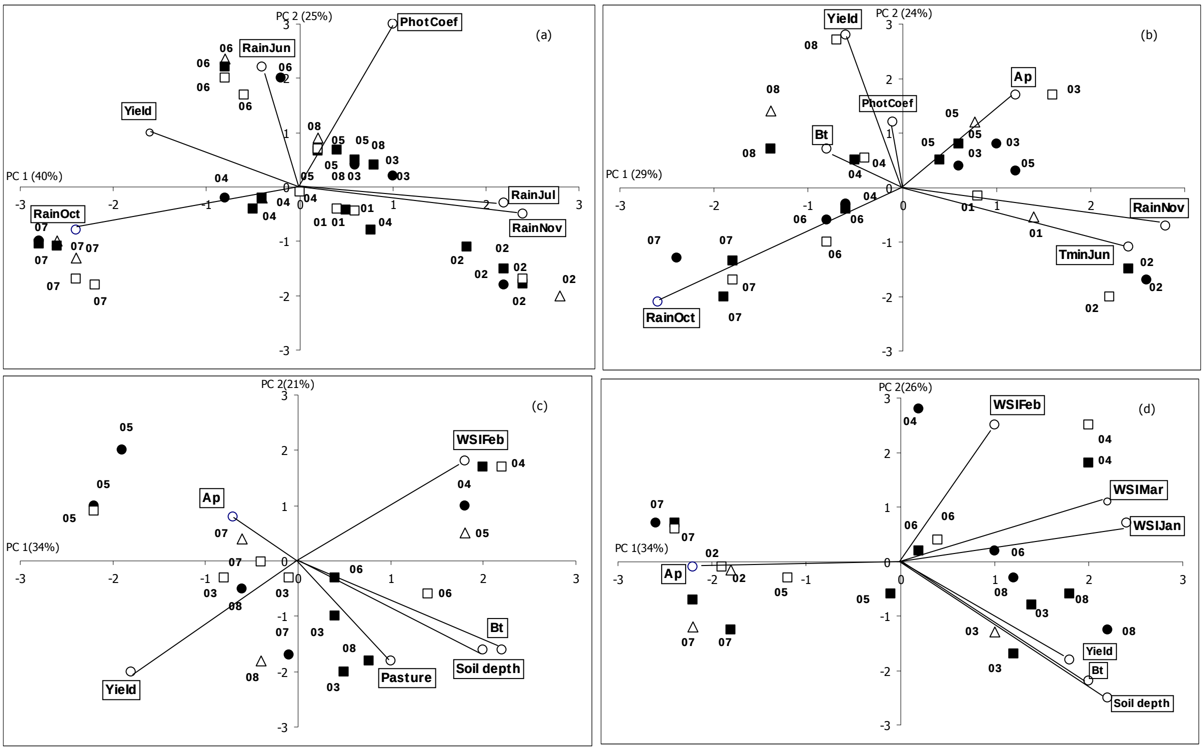

Figure 2. Effect of year-treatment combinations on the first and second principal component of overall observations for wheat (a); barley (b); soybean (c); sunflower (d).

Points represent the principal component score of each tillage-rotation combinations from 2001 to 2008. Empty circle=$LC_{C\text{-}LP}$; full circle=NT_{CC}; full square=$NT_{C\text{-}LP}$; empty square=$NT_{C\text{-}SP}$; Line followed by circle= principal component; numbers=year.

An adjusted winter crop technology composed for early seedling, crop rotation and nitrogen management has been proposed to mitigate negatives consequences of NT systems in these conditions (Passioura, 1992). In our experiments wheat and barley were planted in optimal seedling date range every year; nutrition was defined according to an Uruguayan model proposed by using soil and plant test critical level established for each crop; crop sequence was established in order to reduce disease risk (Krupinsky et al., 2004); and weeds were controlled. All these practices most likely reduced the differences between tillage treatments in relation with similar studies cited in the literature.

Grain yields were shortly modified by pasture inclusion. Ernst (2000) obtained lowest relative yield in NT system for the first cropping cycle following the change from conventional tillage (CT) to NT system. This negative effect was reversed during the second cropping cycle and NT yields were higher than CT yields after that. These results were explained by an improved crop technology, primarily in the length of the fallow period defined as days between glyphosate application to the pasture and crop planting. Because our results correspond to yields obtained 6 years after the installation of the experiment they are comparables to second cropping cycle results.

Sorghum grain yield was not associated with water stress index variables or treatment. Sorghum is a recognizable water stress resistant crop. Its grain yield has been negatively associated to low sunshine hours and low temperature during filling grain but not associated to rainfall records during growth season (Gonnet and De León, 1984a).

Only soybean grain yield was significantly reduced in $CT_{C\text{-}LP}$ (Table 2) and WSIFeb showed the strongest negative effect regardless of the treatment (2004, superior right quadrant in Figure 2c). In NT systems and medium WSIFeb soybean yield was reduced only in shallow soil (less than 0.4 m) (superior left quadrant). The inclusion of a perennial pasture did not affect crop yield.

No-till, low WSIJan and depth soil was the best combination for high sunflower grain yields (lower right quadrant in Figure 2d). Low yield of NT_{C-SP} treatment (Table 2) was more defined by a combination of dry year (2004) and shallow soil (2002, 2005 and 2007) than a negative effect of crop-short rotation.

While soybean was planted early in December immediately after wheat harvest, sunflower was planted in early October. For this reason, sunflower yield was more negatively associated with WSIJan than WSIFeb. Thus, sunflower critical period for grain yield (i.e. flowering and grain filling) (Cantagallo et al., 1997) occurred during the month of January and February and critical period of soybean (i.e. grain filling from R4 to R6) (Calviño and Sadras, 1999; Giménez, 2007) did not occur until February.

Results obtained in soybean and sunflower agreed with those reported by Sadras and Calviño (2001) in Argentina. They established that grain yield of soybean and sunflower decline 0.45% and 0.54% per centimeter reduction in soil depth respectively.

According with our forty-two months of mixed grasses in rotation with forty-two months period of double annual cropping sequence does not improve grain yields of the annual crops in NT system. Neither including a short pasture period of eighteen months (NT_{C-SP}) had a positive effect on yield of crops. The highest total grain production obtained in Uruguay from 1963 to 1989 in crop-pasture rotation with relation to continuous annual cropping (Fernández, 1992), was using conventional tillage. However, Ernst (2000) found that crop yields were higher in no-till than conventional tillage systems and no significant difference in wheat yields were found between no-till crop-pasture rotation and no-till continuous annual cropping system.

In CT, higher crop yields in crop-pasture rotation compared with continuous cropping were explained by an improved soil quality (Fernandez, 1992). However continuous cropping in NT maintained soil organic carbon and means soil weight aggregates in relation to crop-pasture rotation (Ernst and Siri-Prieto, 2006).

The better performance observed in NT systems in the present study is in agreement with Strong et al., (1992), Elliott et al., (1994), Díaz-Zorita et al., (2002) from studies conducted in Australia, US and Argentina respectively.

CONCLUSIONS

Our results indicate that the amount of rainfall and its distribution over the growing season were the most strongly influencing variables affecting crop yields in Uruguay. Multivariate analysis of crop yield indicated that the use of NT had not negative effects on grain yields on the evaluated treatments. Although an important effect of weather condition during growth season of the evaluated crops was observed, there were not evidences of interaction with tillage or rotation systems.

Soil depth was important to obtain high soybean and sunflower yield in NT systems but only in mild water stress conditions.

In NT treatments, continuous double annual cropping systems resulted in similar grain production than both crop-pasture rotations evaluated.

Inclusion or not of pasture in rotation with intensive and diverse double annual cropping systems and adjusted crop technology would be more an economic than soil management decision.

If CT_{C-LP} system is converted to any NT systems, the data from this study strongly supports that there will no negative effects on grain yield production of crops.

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